CHAPTER 5.—A MODEL OF THE JUDGMENT AND DECISION-MAKING PROCESS IN MINE FIRES

Various aspects of judgment and decision-making are key themes in this book. The model presented here serves as a loose structure for the chapters that follow this one. The notion of a model is introduced because growing research interest in the subjective aspects of group and individual behavior has led to a debate over whether judgment is a skill that can be understood scientifically. A related point of contention is whether such an understanding could lead to the development of methods for estimating people's ability to make good decisions during an emergency. There is some literature that supports the potential usefulness of this approach. However, little agreement seems to have been reached on how to define and operationalize even those basic concepts necessary to assess the soundness of decisions from within their environmental and group contexts [Jensen and Benel 1977; Godden and Baddeley 1979; Baumann and Bourbonnais 1982; Brecke 1982; Stone et al. 1985]. A look at the real-world process is clearly needed.

The need to attempt a better understanding of judgment and decision-making properties stems from those occasions in the existence of an organization when there is a lot at stake. The process of decision-making (which is part of the exercise of judgment) has been analyzed in situations such as corporate takeovers [Janis and Mann1977], military combat [Begland1979], clinical emergencies [Baumann and Bourbonnais 1982], and aviation events [Billings and Reynard1984]. The fundamental assumption of these analyses is that, while there are untold successes, there are also notable numbers of failures resulting from decisions that can be ascribed to one or more errors in judgment. From a cognitive perspective, any person engaged in decision-making (either alone or in a group) is actively involved in a process characterized by certain elements. These were mentioned in chapter 1, but are reiterated briefly at this point: (1) detection of a problem, (2) definition or diagnosis, (3) consideration of available options, (4) choice of what is perceived as the best option given recognized needs, and (5) execution of the choice based on what has transpired [Flathers et al. 1982; Baumann and Bourbonnais 1982]. At any moment in this process, there are factors at play that have a large impact on one's ability to solve complex problems in a limited time: (1) an internal state [Hedge and Lawson 1979] is the sum of a person's psychomotor skills, knowledge, attitudes, etc.; (2) uncertainty [Brecke 1982] is caused by faulty or incomplete information received from the external environment; (3) stress [Biggs 1968; Jensen and Benel 1977] is generated both by the problem at hand and any background problem that may exist; and (4) complexity, as it is used here, refers to the number of elements involved that must be attended to. These variables are depicted in figure 5.1, and their relationship to each other and to an outcome is indicated. This schema is designed to suggest interaction, because while the judgment and decision-making process may be conceptualized as discrete stages, experience tells us that this is not the way people function in real-world situations.

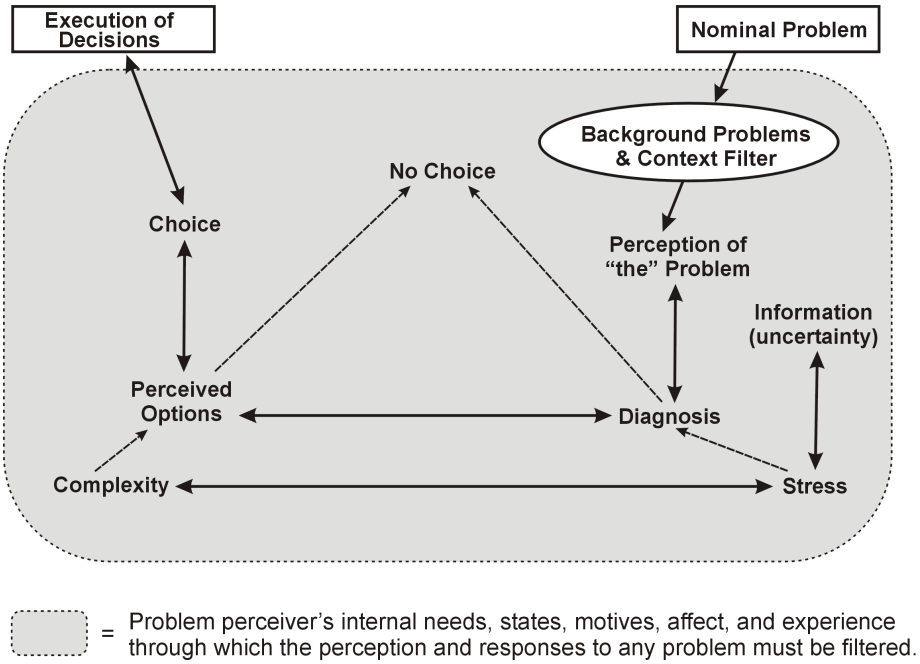

Figure 5.1.–A model of judgment and decision-making.

The interactive model reflects underlying demands on decision-makers in most life or death situations. Whether the individual is an airline pilot, a fire-fighter, a nurse, or an industrial worker, an emergency makes it necessary to deal with an enormous amount of sometimes faulty information in a rather short time-frame. While (ideally) an understanding of judgment in the context of one event should be generalizable to comparable circumstances in different environments [Jensen and Benel 1977], judgment theorists have typically limited themselves to more specific approaches. The method they have most often used to examine empirically a given aspect of judgment is usually some variation of the situational technique. In situational exercises, the subject is presented with a problem taken from his or her area of competence (aviation, for example) and is given the task of reaching a workable outcome. A majority of existing exercises appear to focus on either one of two elements represented in figure 5.1: (1) an individual's ability to reach a satisfactory diagnosis once he or she has become aware that a problem exists, or (2) a person's choice response after a scenario has been laid out and the diagnosis provided.

Using Judgment and Decision-Making Skills in a Mine Fire

This chapter, rather than reporting the results of subjects' performances on a simulated problem, discusses instead how these eight case studies deal with the

complete process of peoples' judgment and decision-making during an actual event (group escapes from a mine fire). Throughout each episode, workers engaged in an ongoing series of activities, some of which seem to have been well thought out and others that (in hindsight) do not seem so logical. Yet, all the while, they were attempting to solve the problem that confronted them. Such behavior is in line with much of the recent literature dealing with human actions in fires, which advances the argument that people engage in adaptive behavior based on choices made from among those perceived to be available at any particular time during the occurrence [Sime 1980; Lerup et al. 1980].

People seem to exercise judgment and make decisions during a fire, although they oftentimes fail to perceive the fundamental problem adequately. This is especially true if they are focused on a task, or are having some type of difficulty. An act that appears irrational when viewed with the 20/20 vision of hindsight, therefore, might have seemed, to the actor in that situation, the most sensible thing to do. Unfortunately for those interested in reaching a more objective understanding of the quality of those decisions, choices are usually judged ex post facto depending on their outcomes. Accordingly, if a person survives, he or she is credited with making sufficient correct decisions and little attention is paid to poor choices; if a victim dies, most second-guessing focuses on what he or she might have done wrong and there is not much analysis of any good decisions that were made.

The settings of this study seem particularly appropriate for an examination of topics such as the quality of thought that goes into choices made during an emergency. That is because mining lore is filled with accounts of tragic outcomes that could have been avoided. Many stories recount how escaping workers advanced to within a few feet of smoke-free air, yet chose to turn back and barricade, perishing in the end [Cole et al. 1988]. The real question then becomes not one of whether the instrumentally "correct" choice was made (it is known in retrospect that this was not the case), but whether those miners made the best use of all evidence available to them in reaching the decision they implemented. To put this another way, outcomes might not always be linked mechanically to the quality of choices. This chapter will show how the qualitative database is being used in the formation of a framework that ought to allow a better understanding of miners' judgment and decision-making activities given such a scenario.

Fire in the Mine as a Nominal Problem

In the model used here, a nominal problem is defined as an environmental or system condition that can be characterized by the type of response it requires [Pew 1994]. Fire is one of those events needing a high level of "situation awareness." Endsley [1988] has identified this concept in terms of its three main components: (1) perception of a situation's elements in time and space,

(2) comprehension of their meaning, and (3) projection of a near future status for the condition in question. Endsley's notion of situation awareness closely parallels two stages (problem perception and diagnosis) shown in figure 5.1 and is discussed below as part of the judgment and decision-making process. The present section offers a brief description of the nominal problem at each study site.

Adelaide Mine

At 9:08 p.m. during March 1988, Adelaide's second shift dispatcher was alerted by a warning of 10.5 ppm on the mine's carbon monoxide monitoring system. This warning cleared almost immediately. A few seconds later the same sensor (at the end of 2 Northwest belt) registered a warning of 11.5, but cleared in less than 30 seconds. The dispatcher continued his normal duties. Sometime after 10:00 p.m., a third-shift supply boss arrived at Adelaide's surface facility:

> I always go to work early, I did all my life. I reported to the mine and I put my dinner bucket down, and I went out to the lamp house to get a cup of coffee. When I entered the lamp house area I heard this beeping sound. It was coming out of the dispatcher's shanty...I walked in and what it was was the CO monitor...I want to know what's goin' on. And they says the monitor's been goin' off and on, and we think we got a fire, but we're not sure. Well, I said, was the crews notified inby the fire area? No we didn't notify anybody yet 'cause nobody contacted us. So I said you better start calling these crews and get them out of the mine whether you know it's a fire or not, you better get a hold of 'em.
>
> At 10:30 I entered the mine. We got up there and they were already trying to fight the fire. We fought it for a good while and we kept losing ground continuously. It just kept going way ahead of us.

Workers continued to fight the fire, which was reported to be in or near the drive head of 2 Northwest's "mother" belt (see figure 2.1), with small foam generators, fire extinguishers, water, and rock dust. By that time, all section crews had been notified to evacuate.

Brownfield Mine

Around 11:00 one summer morning in 1988, a "fire boss" (mine examiner) was in the process of inspecting Brownfield's No. 38 belt conveyor. This belt receives coal from sections being developed off 6 West Mains section and also transports coal from 6 West Mains itself (see figure 2.2). He had arrived just

outby the "head drive" (terminus) of 5 South section's belt when he smelled smoke. The fire boss first checked the 5 South belt head, and finding nothing wrong there, walked approximately 600 ft along No. 38 belt to the 4 South head drive. At this point, he detected smoke farther down the 38 belt toward the 3 South head. Continuing along the 38 belt, the fire boss walked another 200 ft to the worked-out 4 North drive area, at which point he encountered heavy white smoke. Retreating back along 38 belt to the 4 South head, the fire boss entered the track entry of 6 West Mains, where the smoke was somewhat less dense. The fire boss hurried along the track back to the old 4 North area, and stopped at its head:

> I could hear...a rumbling like a—at first I thought it was the welder in there burning something and something happened in there...I yelled for...the welder...I yelled about two or three times for him and there was no answer...I run back over and I went through the overcast to go over to the intake...which would be the right side of the track...When I got in there, the smoke was real thick in there too, and I couldn't see...So I dropped down on my knees and I turned around to get my W65 [filter-type self-rescuer] off of my belt...When I kneeled down, I could see the yellow door...So I hurried up and went over to the door, opened that door and got out through there and I was in the intake then...I was coughing around and it really burned my chest at this time, so I probably stayed there a couple minutes to get my bearings again and I went down—I had to go to the intake to 3 South, so I run down the intake... This is—we're talking 4½ feet, so when I say run—I went down the intake to 3...and I came out onto the track and it was clear...So I run up the track then to 4 South and there was...a high spot where they took rock...The smoke was like hanging there and it was clear outby the high spot...The smoke was real thick, but along the left rib, I could see where there was no—it was clear...So I crawled up along the rib, stayed real low, and I crawled up along the rib, cause I still thought [the welder] was in there and...something had happened...I thought there was a man in there...I went up along the rib and I got my head around the corner and I looked in and I yelled...a couple more times and I could see the flames coming off the top—I could see that there was a motor sitting there...I saw the flames coming off the top of the motor.

After seeing these flames, the fire boss disengaged the trolley power by opening a cutout blade. He then called to warn his shift foreman and those miners working in each of the three sections that would be affected by the fire. The fire boss was soon joined by the mine foreman and general assistant mine foreman, who helped him fight the fire. Meanwhile, the three affected section crews were being warned to get out of the mine.

Cokedale Mine

At some time during an early morning in October 1990, a roof fall occurred on one of the haulage tracks at Cokedale Mine. The operation differed from most mines today because primary coal transport was still done by rail. One set of rails was used to move loaded cars and adjacent tracks in a parallel entry were employed for empties. Crossovers were located at intervals along the haulage so that cars could be switched back and forth. It was at one of these crossovers that a lead motorman, bringing a trip of empties into the mine, saw smoke. After alerting his buddy in the trailing motor, this worker dismounted and went to find what he believed was a burning trolley switch. The lead motorman had walked only a few feet into that crosscut where the crossover and trolley switch were located when he encountered heavy smoke.

The lead motorman retreated to his locomotive and attempted to clear the track. Before he could push his 45-car train to the next crossover outby, power went off and the motorman was forced to park his trip on the empty track. At the train's rear, the trailing motorman cut his locomotive loose and was able to coast into the crossover and onto the loaded track. As he drifted down this track, the trailing motorman saw a roof fall with the trolley wire under it and flames coming from the caved material (see figure 2.3). After calling outside to report his discovery to the dispatcher, the trailing motorman grabbed a fire extinguisher from his locomotive and went back to the burning cave-in. Near the fire site he met the lead motorman and these two workers attempted to fight the blaze. Meanwhile, the dispatcher was busy notifying those miners inby the source of combustion that smoke was coming their way and relaying the fire's location to them. The affected miners began an immediate evacuation.

Perception of the Nominal Problem

There are two ways in which any warning about the existence of a problem may be conveyed to an individual: by means of some intermediary; or directly, through the senses. In the first instance, a person is faced with the task of deciding whether to believe the messenger and/or how to interpret the message. In the second instance, a person is faced with the necessity of drawing implications from what his or her senses are revealing without benefit (in many cases) of corroboration. Under both of these conditions, perception is a process that involves a varying degree of uncertainty. The process also requires time, during which a perceiver attempts to get a fix on the problem and begin his or her diagnosis. A lot depends on situational factors. In the model depicted by figure 5.1, these situational factors are shown as a context filter. There were aspects of the context at each operation that had a distorting effect on how the nominal problem was perceived.

At Adelaide, the nominal problem was a fire on the mother belt. There were two factors confounding a grasp of the true situation at this site. First, on the night the fire occurred, affected sections had been plagued all shift by belt stoppages. Second, recent technological developments at this mine caused the initial message to be mishandled. Several weeks prior to the fire, new sensors had been installed near the mouth of 1 Right. Maintenance people doing this work drilled holes in the tops of the sensor boxes and secured them directly to roof bolts. That action seems to have established some sort of ground potential which was keyed by signals from passing trolley motors. This ground potential in turn triggered alarms on the monitoring system outside. When the problem was fixed by rehanging the sensor boxes, another predicament appeared. Some sensors in the area were still giving false alarms. Further investigation showed that new 19 gauge wire connecting those field data stations was defective. In essence, because of technical problems, Adelaide's dispatcher had been inundated with false alarms for some time preceding the event.

The nominal problem in Brownfield's case was the burning motor located at 4 South, 6 West. A compounding factor, which no one knew at the time, was that a door had been left open in the supply chute where the motor was parked. This open door affected ventilation inby the blaze, and caused the smoke to behave in ways that the miners did not anticipate. Because of their internal state, made up in part by knowledge about how the ventilation system normally functioned, these workers were led to misapply environmental elements in making their diagnoses. The result was that many of the miners came to view the problem as far worse than it actually was. Consequently, their decisions were, in some instances, based on false assumptions and the resulting actions were not as effective as they might otherwise have been.

At Cokedale, the nominal problem was a fire that started when fallen material from the mine roof caused a trolley wire to arc. Although the person who discovered this blaze contacted Cokedale's dispatcher and reported what he was seeing, initial communications were misconstrued. The reason is that with trolley haulage "hot hangers" occur fairly often. A hanger is an insulated support bracket that suspends the trolley wire from a mine's roof. When an insulator deteriorates, the support pipe that extends into the top will heat up. If there is head coal in the mine roof, this coal may start smoking. In most circumstances, a hot hanger will be dealt with by disconnecting the power, prying down any head coal, and replacing the hanger assembly. Thus, when the dispatcher began contacting people inby the fire source and, according to several respondents, initially spoke of "a hanger burning" no one was particularly alarmed.

Thomas [1923] argued that people's actions generally depend on their definition of the situation. It has already been suggested that miners are conditioned by both their physical and social environment to define situations

in certain ways. Danger is a taken-for-granted aspect of underground workplaces. It is necessary, then, for workers in such a setting to draw a distinction between routine hazards and life-threatening occurrences. In other words, any warning stimulus must make it through this sort of context filter in a manner clear enough to cause a situation to be perceived as problematic. Mallett et al. [1993] listed five characteristics of an effective warning: (1) it will be specific about what the problem is (2) the warning's validity is acknowledged, (3) it gives the nature and extent of danger to those who are threatened, (4) the warning will be verifiable, and (5) it will contain some cues to help people prepare for further action. The paragraphs that follow will discuss how initial warnings were received at the three study sites.

1 Right - Adelaide

On Adelaide's 1 Right section, the message that there was a problem came by telephone. Both shuttle car drivers were cleaning up around the feeder because their belt had been running erratically and finally went down entirely. They first heard someone on a trolley pager trying repeatedly to contact another section. Then, the 1 Right telephone began ringing:

> I said, "There's something wrong, buddy...I better answer the telephone." So I went to the telephone, I picked it up and I said, "Hello." Nobody answered. So we waited there again to about five till [eleven]; the telephone rung again. I picked it up and I said, "Hello...Who is this?" And it must have been the dispatcher because he told us, he said, "You got a fire on the belt, get the men out of the section." I said, "This is 1 Right." He said, "Go get your men out of the section. You got a fire on the belt."

The shuttle car drivers, joined by a bratticeman who had been helping them at the feeder, set out to warn those workers at the faces. The bratticeman took the left side, one driver went up the middle entries and the other took the right side to warn 1 Right's miner operator and his helper.

The bratticeman found the two bolter operators in No. 3 entry. Since the bolter was running, they had difficulty communicating:

> Well, first we shut the machine off, because we couldn't hear him, what he was saying, and then after he told us...there was a fire—or they said there was a fire on the belt; that everybody was supposed to leave...I just pulled my boom back and stopped everything, shut the power off, got my coat and bucket, and went down to the load center.

The shuttle car driver who had taken the right side first approached his boss, who was making a preshift face examination:

> I told him the dispatcher said an alarm went off and there was a fire in the mine and everybody had to get out. And he said, "Well, tell the operators." He went and kept walking along the face. I think at this time, we still didn't think it was a fire. We thought it was just an alarm.

Whether this attitude affected the manner in which the shuttle car driver approached the operators is somewhat unclear, because he recounted that "I told the operator, 'There's a fire in here, just back up and go.'" Both men on the miner, however, remember this warning somewhat differently:

> One of the buggymen come running out, and he was like three breakthroughs behind us. All he did, he just hollered up and said, "Hey...back the miner up, we're going home." I said, "What's the matter?" He says, "I don't know; all I know is we're going out."

The miner operator and his helper, oblivious to the fact that an emergency was developing, went through normal shutdown procedures and retrieved their personal articles at the load center. They then strolled to the mantrip, where everyone else was waiting impatiently to depart.

2 Northwest - Adelaide

Smoke, or the smell of smoke, arrived on 2 Northwest before the workers could be contacted. One of the shuttle car drivers, who had prior experience in fire as a mine rescue team member, was the first to sense something wrong. Like the buggy operators on 1 Right, he and his buddy were not running because the belt was down:

> [While] we cleaned around the feeder, ...the other buggyman for that night...was standing there with us talking and I told him, I says, "I smell rubber."...I looked down the belt, and I...smelled the smoke then, and I immediately went into, I think it was 4 or 5 [entry]...into the face... That's where the boss was...and I told him..."We got a fire or something went wrong with that belt again...Are you going to call?"...So he went immediately to the phone and called, and he said..."We got a fire on the belt."

Both shuttle car operators went to warn those workers still at the faces. Their boss remained by the telephone. While the miner operator remembered only that

a buggyman started flagging him and said "smoke," everyone else was clear that they had been informed there was a fire on the belt. All miners were also told, they remembered, to gather fire extinguishers. Most of them did so and headed to their dinner hole. From there, they boarded their personnel carrier for an attempted trip out of the section.

3 Left - Adelaide

Workers on 3 Left reported that their section foreman was near the telephone and, when it rang, started to answer. It stopped ringing:

> Then they rang right back again and he said, "Come on, let's go." Everybody said, "Aw, we got to go down and shovel the belt..." So we were moving kind of slow and disgusted. And then he yelled again, "Come on—there's a fire on the belt—let's go!"

The boss notified all face workers and told them to back their equipment out and shut it down. Power was knocked at the load center and everyone went to their mantrip.

4 South - Brownfield

On 4 South, at Brownfield, one of the shuttle car drivers heard the pager as he was dumping a load of coal on the feeder:

> Fire boss was on the phone...He says, "...There's heavy smoke coming into the intake...get out of there as soon as you can—get those men out..." I didn't even finish unloading the buggy...I just turned around on the seat and went back up to the miner...the bolters were in there and I stopped at the bolters first and I told them that there's heavy smoke coming up the intake and we're supposed to get out of here right away—see you back at the power center—that's where the [self-contained self-rescuers] were.

When the bolters heard this warning, both of them surmised that it was only a drill. They knew that a system for sensing fires was being installed and assumed that fire drills would be planned to test the new system. The bolters further reasoned that the presence of an inspector on their section made a drill more likely: "We had that inspector in there and I thought it was like a fire drill, just to see how long it took us to go to our meeting place...get our equipment and stuff...I. wasn't that excited about it." The shuttle car driver next went to tell the miner operator and his helper, who "backed the miner back...[and] went back to the power center."

When the face workers arrived at their power center they found that the section foreman, mechanic, and a Federal inspector had already gotten there. These three were told about the fire boss's call. The section foreman had realized that there was some sort of problem. He had accompanied the Federal inspector and section mechanic to repair a scoop that was out of compliance and parked in a crosscut outby the section's transformer:

> I guess what was happening, smoke was coming up the intake and everybody didn't realize it...it was going past us...we were so far back into the crosscut...we were there working and I thought I smelled something burning...I asked everybody if they smelled it and they said yeah, they realized they did smell something...I went out to the aircourse, No. 2 aircourse, and I could see the heavy smoke was already up there, so I just told them there was a lot of smoke out there.

Thus, by the time the workers had assembled at the power center the section foreman was able to corroborate the warning everyone else had gotten through an intermediary. What was lacking was any information about the location and magnitude of the problem.

5 South - Brownfield

On 5 South also, the first warning was delivered by means of the mine page phone. The call to this section was taken by one of the shuttle car drivers:

> I heard them calling 5 South on the phone, so I went and I answered the phone...They asked if the boss was there...I said yeah...so they said tell the boss to get everybody out of the section because they had heavy smoke coming...I did get a little bit excited at first, and then I...called back [to ask] them...where it was coming from...and didn't get no answer.

The fire boss's message, already inadequate, was relayed by the shuttle car driver to his section foreman:

> The belt shut off...[the shuttle car driver] come over and said that [the fire boss] called and said there's smoke coming up the belt line...[the shuttle car driver] didn't wait...I asked him is it bad, and he said I don't know...He just said we was supposed to get out.

The roof bolter operator and his helper, deciding to take a break while the belt was down, were the next individuals to be informed: "My buddy and I...were

walking back to get a cup of coffee and the buggy runner [shuttle car driver] hollered that there was smoke coming up." By the time the other shuttle car driver received word of the fire, he had already been alerted by the smell of smoke. He primarily wanted more information, which his fellow buggy runner did not have:

> We was loading in No. 2 entry...the belt went off...While [the shuttle car driver] was answering the phone...I was over at the intake, and I could smell the smoke coming in already...So then [the shuttle car driver] come through the crosscut and told us things...[The fire boss] told him there was going to be smoke coming and we better start out, but [the shuttle car driver] didn't wait and see where the fire was and all that, which he should have done.

It can be seen from these comments that the workers on 5 South, like those on the other two sections, began their evacuation without an adequate perception of the nominal problem upon which to base their diagnoses.

6 West Mains - Brownfield

On 6 West Mains section, where three people were working, the initial warning came in the form of a page phone message taken by a maintenance foreman. This individual was accompanying a mechanic and a State mine inspector on an inspection:

> "I heard the fire boss...and I recognized from his voice that he was really desperate to get somebody to answer, so I went to the phone...and he said there was a mine fire at 4 South, 6 West."

At that point, although the maintenance foreman had been told the fire's location, he had no notion about its severity. Nor had the foreman gotten a chance to reinforce the sense of desperation he detected in the fire boss's message through the medium of his own senses.

Though he was predisposed to believe there really was an emergency and to act upon that belief because of the urgency he discerned in the fire boss's voice, the maintenance foreman still "didn't really think....it was anything to...get concerned about." One reason he did not become concerned at the first warning of fire was undoubtedly because of his internal state, which had been conditioned by past experience with smoke in the mine. The foreman had seen "lots of mine fires, small mine fires...I've been in where...belts slipped and burnt halfways off the roller and stuff like that." Since smoke is fairly common in the mining environment, miners do not always interpret its presence as an indication that immediate action should be taken.

After hanging up the pager, the foreman first went to alert his mechanic. This worker, because he was involved in the complex task that had made it necessary for him to be on this section in the first place, was not paying attention to what was going on around him:

> I hollered to him from the phone and he didn't come...He said, "Wait a minute..." and I went down to where he was and says, "Come on... There's a fire in the mine down 4 South."...He said, "Just a minute."

Telling the mechanic not to wait any longer, the maintenance foreman then went into the belt entry to inform the State inspector: "He was over there at the feeder, and that's the first sign of smoke that I seen was outby the check at the belt entry." Thus having the fire boss's warning substantiated, but still not knowing very many details, the men began their evacuation.

7 Butt - Cokedale

Initial warning came indirectly to 7 Butt when a construction foreman, listening on his trolley phone, monitored talk between the lead motorman who had been bringing in empties and Cokedale's haulage foreman:

> I was sitting at old 8 Face and when he said about the trolley switch burning I turned my light in the opposite direction, because the air comes straight down...from the new intake aircourse and there was just a solid wall of smoke behind me. So I called the dispatcher and told [him] to get in contact with all the people in 8 Face Parallel and get them out because all the smoke was going in on them.

The construction foreman then went into 7 Butt to alert a fire boss, two mechanics, and four others working in the section. Because of the conversation he had overheard, the construction foreman told those with whom he spoke that a trolley switch was probably burning:

> He...thought it was a wire fire, you know, like a trolley wire. We have a lot of them down there, so you don't have to be worried about it too much...Everybody took their time. So me and the mechanics...even took the time to put the tools away.

This group, led by the construction foreman, elected to ride jeeps and a portal bus out the track entry.

8 Face Parallels

A general foreman was with two men cleaning up a roof fall. Needing some large reinforcing bolts, he had been scouting in the 8 Face area. After finding the materials he needed, the foreman sent a worker to retrieve them. In the meantime, he ate a sandwich and waited in the old section switch at 8 Face:

> There's a phone there. I saw some smoke coming up the track entry. I called the dispatcher...I said, "What we got here?...I'm getting some smoke up in here." He told me at that time, he said, "Maybe a hanger burning, or something."

The general foreman sent a worker into the 8 Face Parallels section to warn everyone there and tell them to gather near his location. While he was waiting, the foreman was joined by two motormen who were bringing a load of rails into the area. In all, eight miners rendezvoused with the general foreman. These men then attempted to walk out through their track entry.

In essence, miners in all eight groups received some sort of warning, following the discovery of fire, telling them either that "smoke" was headed their way or that they needed to leave the mine. At this point, however, most workers seemed to be acting "as if" there was a problem that required action, but were not too concerned about their chances of getting outside: "Well, at first nobody really thought too much of it, you know." It was not until their perspective was challenged by an unexpected occurrence that the miners began to diagnose their problem as a serious one.

Diagnosis

It is axiomatic that people tend to interpret events from a normal perspective as long as they can before starting to define the situation as abnormal [McHugh 1968]. This notion is illustrated by the initial misdiagnoses of those who discovered the nominal problem at each study site. Adelaide's dispatcher, for whom unreliable sensor readings had become routine, did not accord legitimacy to the first actual warning he received: "I took it as a false alarm." The fire boss at Brownfield also saw the event incorrectly when he initially encountered smoke: "I stood up and I smelled smoke. I just kind of thought it was, you know, maybe a bad roller, the belt was rubbing on the straps, or something like that because we've had that before." The haulage foreman at Cokedale seemed, to those who overheard his trolley phone exchanges, complacent about the problem he was facing: "I even heard him talk to the people [outside]. He said, "Look in my locker or by my locker and get another trolley switch."' This tendency to normalize circumstances also carried over to the way in which those inby the sources of combustion came to diagnose their situations.

1 Right - Adelaide

The crew on 1 Right had their evacuation delayed due to miscommunication between a buggyman and the operators he went to warn:

> We were just taking our good old time...There was no smoke; you couldn't smell anything...It was clear, you know...I said..."Really, what's going on?"...And [a buddy] said, "I'm telling you, the place is on fire."

Actually, it was not until the workers encountered heavy smoke that they began to realize they were in a potentially deadly situation. Group reliance upon normalcy gave way at that point to a change in the way they construed their condition [Kinston and Rosser 1980]. What had been considered a routine evacuation became disrupted:

> You could smell the coal actually, and we started pulling the self-rescuers out and passing them around...Three guys run over to the intake...and they were just—we were running, you know, here and there..."What do we do—what do we do?"

Very soon, however, the workers began to take stock of their predicament. At this point they were actively seeking information that would let them make sense of what was actually happening:

> Common sense tells me if there's a fire, chances are the fire is going to be in the belt entry. I'm also thinking if the fire is there, the fire wants to go for fresh air. It can be fueled by fresh air [in the intake]. And I didn't want to go the belt entry...Let's get into the return and find out what we have.

As the group's evacuation turned into an escape, everyone tried to fill information gaps with guesses about the fire's location and how best to proceed. The way in which they filled these gaps would have an impact on the perceived options as their escape progressed.

2 Northwest - Adelaide

There was no initial question of whether *something* might be wrong on 2 Northwest; rather, group members became concerned with the *extent* to which something was wrong. On this section, even with the smoke that was present, a few workers tended to downplay the seriousness of what their senses were telling them. This behavior, normal for the early diagnosis stage, is typified in a comment made by a bolter operator:

> I figured, well, with all the safety features that are supposed to be built in this, they got a little fire down there and the smoke coming up and they want us the heck out of here, but I figured...we're going down with fire extinguishers, I figured we'll ride down in a mantrip, come to it and—we got the fire out, if there ain't somebody already down there to get it out. It was my feelings.

The least amount of minimizing was done by the buggy driver who had voiced an alarm originally. This person was a former mine rescue team member and had experience in smoke:

> I started to get a fire extinguisher off of the miner at that time, and the smoke was getting pretty bad then. And so I said, well, to hell with the fire extinguisher. I'm going to, you know, take care of myself.

As can be seen, even where individuals had smelled rubber, seen smoke, and heard their section boss confirm they had a fire on their mother belt, there was variability in how a diagnosis was reached.

3 Left - Adelaide

Like the bolter operator quoted above, one of the workers on 3 Left also thought his crew was leaving the face to fight a manageable fire:

> They said, "We got a fire on the belt. Back the machine out and let's go." Well, I just felt we'd run down and put it out. I didn't think there was any real major [problem], they said it was just a small [fire], burning on the belt. Well, if that's all there was to it, we could have took a fire extinguisher, run down there in the mantrip [and put it out].

When the group encountered heavy smoke they became disoriented and lost their way momentarily. This added an element of uncertainty that made an accurate diagnosis of their situation all the more difficult. That, combined with the fact that they did not know where the fire was, prevented them from reaching a clear picture of what was required for everyone to reach safety.

4 South - Brownfield

On 4 South, the workers had decided to travel down their belt, which was isolated by stoppings from the intake and return entries:

> I walked over to a door in the belt entry and saw that it was clear air... There was no smoke coming up the belt...I just run that belt on the day

> prior to this and I know the stoppings were intact...So the belt entry should be clear if there was a problem in the intake.

Some of these miners expected to encounter light smoke in their belt line (because of a possible leakage through the stoppings). When this indeed appeared to happen, a diagnosis of the real nature of their problem was confounded by stress induced from having to deal with a relatively unfamiliar breathing apparatus:

> We stopped and everybody knelt down and started putting their [self-contained] self-rescuers on...when I looked over and saw the...miner operator, that's about the first time I started getting a little worried because he was shaking somewhat severely...and I just thought...we are going to have trouble because he's having a hard time even, you know, getting his self-rescuer cover off.

> I got the machine on and started down there and I wasn't getting the air that I thought it was going to give me...So I took the mouthpiece out... you need to breathe and you're not getting what you're supposed to.

Focusing on these perceived problems with their self-contained self-rescuers, the workers did not anticipate meeting heavy smoke during their evacuation. Therefore, when the miners did encounter dense smoke in their belt line, they were presented with an extra (and unexpected) experience.

This new occurrence, however, was one that stemmed from their environment rather than from a piece of technology. It was this second event that caused them to begin diagnosing their situation as very serious indeed: "I was thinking, I remember distinctly thinking to myself, all this smoke around...I can't even see...You couldn't even see where you were going." Choices made by these workers later in their escape, then, were based on the necessity of dealing with apparatus that did not perform as expected in conditions the miners had not foreseen.

5 South - Brownfield

The predicament of heavy smoke in areas that were supposed to be isolated was also unanticipated by the workers who escaped 5 South:

> We turned around and we were going to go down the intake and we didn't get more than 50 feet when we could see the smoke coming in towards us...one of the bratticemen said we'll get into the belt line 'cause it's neutral air...Everybody got up in there and...we only went maybe

two, three hundred feet and the smoke was in there—the belt entry...
How it got in there, we don't know...We haven't figured that out yet.

This element of uncertainty stemming from a lack of information regarding the fire source was exacerbated by the workers' internal state. In essence, these individuals knew enough about the mine's environment to understand that (assuming a properly functioning ventilation system) only a large-scale fire would cause contamination of all possible escape routes: "I tell you, panic hit, believe me...'cause all the teaching and training—everything—these are all supposed to be separate splits...Well, the first thing that goes through your mind is everything's burning."

Once the miners determined there was not a smoke-free escape route, then their particular knowledge of the ventilation system led them to diagnose the problem as more serious than it actually was. Additionally, this misperception about why the smoke was behaving as it did caused some of them to consider giving up their escape attempt: "I sat down with those rock dust guys and I figured...this is it...I was just going to say goodbye to the world." The stress engendered by their inaccurate analysis of actual conditions influenced the workers' subsequent choices and actions.

6 West - Brownfield

The men on 6 West Mains began their evacuation knowing that a fire existed at 4 South and that there was some smoke already in their section. The maintenance foreman did not diagnose this as a significant occurrence, though. At the beginning, he had little concern regarding his chances of exiting the mine safely. The maintenance foreman held this notion up to the moment he experienced heavy smoke: "I've encountered smoke [in the mine before], but nothing like this." When the amount of smoke presented irrefutable evidence that things were out of the ordinary, the maintenance foreman stopped defining his situation in terms of past instances when he had seen smoke in the mine. Such a dense collection proved, in his opinion, that the present state could no longer be diagnosed as commonplace. The maintenance foreman then began to perceive the scope of the evacuation problem differently: "Once I seen that smoke, then I got pretty well shook." His subsequent choices came to be affected by that new viewpoint.

7 Butt - Cokedale

On 7 Butt, the construction foreman told all seven people in his area that "smoke was coming in" and they would have to leave. This initial warning did not disturb any worker unduly, as one of the mechanics later recounted:

> We were going to have to get out and—that was about it. We would probably be coming back in after they got the hanger, the little hanger fire put out.

The group, riding in four different vehicles, had not traveled far when they encountered thick smoke in their track entry. Three of the four vehicles, two jeeps and a tandem motor, collided because of poor visibility. The construction foreman drew upon prior experience to reach a diagnosis of what faced them:

> I set all the ventilation up down there, and I knew basically what was going on with all the smoke. The intake escapeway would have been full of smoke. So I told them we'll try to go out on power.

Everyone except three workers in the fourth vehicle, a portal bus, boarded the lead jeep and continued on. After a short distance, however, those five men in the lead collided with a parked vehicle. They and the miners following in their portal bus were forced to choose an alternative plan that would entail escaping on foot.

8 Face Parallels - Cokedale

Nine miners tried to walk out the track entry from 8 Face Parallels. When they encountered heavy smoke on the track, they decided to get into their intake escapeway. After traveling only a few hundred feet, they again found themselves in thick smoke. There was little discussion at this point:

> No, it was pretty much, you know, this is out. Let's try something else. Well, naturally the next thing would be the return. So we decided to try the designated return, at which point [the boss] did not know which was the designated return.

The group entered their left return and went a short distance before discovering they were not in their designated alternate escapeway. By this time the workers were diagnosing their problem as a serious predicament: "That's when it came into my mind...We're in bad shape." This sentiment was echoed by the other group members. The difficulty these workers had in finding their way at the start of their escape had an impact on how subsequent choices were made.

In each case, such a low level of concern exhibited by affected miners at the beginning of their evacuation was due partially to uncertainty about the true nature of the problem. This uncertainty, stemming from incomplete information, allowed the workers to define their situation initially as normal (or at least as nonthreatening). Further into the events, however, unexpected occurrences began to challenge the miners' interpretation of their predicament:

> "We just [put on self-contained self-rescuers] and everybody seemed fairly calm at the time, but then...we got down to the thick stuff...and a sense of panic [set in]...we weren't told where the fire was."

As it became impossible to interpret circumstances from a normal perspective, many of the workers reacted and started to define the fire as perhaps worse than it really was:

> You got one thing in mind—death—believe me...I was scared...I don't think there was a man there that would tell you that he wasn't...I really didn't think I would be here.

Essentially, as can be seen, the miners lacked adequate information to accurately assess the true nature of the problem they faced. Many workers' knowledge of the environment and of how elements were supposed to behave in it combined with their lack of information to mislead them. All of the individuals were in danger, but the real danger was from smoke inhalation—not, as some thought, because their entire mine was burning.

Options and Choices

After completing the diagnosis of a problem, a person must decide which actions, if any, must be taken. This part of the decision-making process calls for recognizing and evaluating available options and then choosing an action that is determined to be best given the circumstances. A number of variables impact a person's perception of particular choices and their appropriateness to his or her situation. Analyses of decision-making therefore must focus not only on the objective outcome of each action, but also (and perhaps more importantly) on choices that were made given the impact of elements influencing the decision-maker. The following paragraphs outline how options were viewed and choices arrived at during the three fires.

1 Right - Adelaide

When the crew from 1 Right, attempting to evacuate on a mantrip, had to stop because of poor visibility, they were faced with limited alternatives. Three miners tried to cross the belt entry to check their main intake. When they opened a door into the belt entry, these men found it to be contaminated:

> And I told them, "Whoa, whoa, wait a second. If you got smoke on your track and when [you] opened the door...I seen you have smoke on your belt, you got smoke in your intake." One of the other guys on the crew, ...who was my buddy that night, says, "Why don't we go back to

> Peterson [shaft] across the bleeder and come out?"...They didn't want to go back to Peterson...I says, "If you don't want to go back to Peterson, then if you have smoke on your intake, we were always taught to get into your return, and then keep checking until you see clear intake."

The group decided their only option was to get into their left return. They found a door and had to pry it open. Before entering this return, the face boss called outside and told the dispatcher what they were planning to do. The crew then started out in air that had not yet become smoky.

As the 1 Right group traveled their return, they were faced with several other points at which decisions had to be made. First, the smoke that had been coming in their intake made its way across the faces and caught up with them near the mouth of 8 Left:

> So we put the SCSRs on. Now one guy's SCSR wouldn't work, so [one of the buggymen] gave him his spare one, and we started to come down this return. And we came to these overcasts down here; you know, one overcast we came on, it was hot and thick smoke was coming out. And after looking at it, it was the belt that was going up to 3 Left, and I mean you could feel the heat coming down it. [The buggyman's] SCSR didn't work and he told me..."I'm not going through that. Mine doesn't work."

So, the buggy runner who had earlier given a spare SCSR to a buddy, now having problems with his own, balked at crossing the overcast:

> I made the decision I couldn't go in this smoke...I was like the third, fourth one in line...and we went into that smoke and I couldn't breathe and I was gagging on that self-rescuer. I couldn't breathe anything at all. I don't know if it was psychological or what...I came back out...I did know where I was because...I'd worked in that area a lot...The other overcast that we just went over was over the intake...So I went back... I went into the door and it wasn't too bad...And I thought I'll go down this way, but then I said, no, if I don't go out with them guys, I know they're going to be looking for me. If they get out, they'll be looking for me and they'll think I'm lost. So I better go out with them guys. So I went back into the return again...I went over an overcast where the smoke was. I went over top of the overcast in the smoke and I couldn't breathe...They were already gone through there. I couldn't see—I couldn't tell where they were because you couldn't see anything over there...I can't breathe. I'm going to die here, and I don't want to die. I don't want to die here. Back into that intake again...So I went...over the stopping—over two overcasts there and got into the intake escapeway at 2 Northwest.

The rest of 1 Right crew continued out their return until they came to a door leading onto 2 Northwest track at crosscut No. 10. At this point, they discovered the shuttle car operator was not with them, and were faced with another decision:

> When we got outside that door, and it was just fresh air, and everybody wanted to take off, that's when I told them..."Hey, [the buggyman] is back there, his self-rescuer didn't work; he didn't come through that." So that's when we went back in...You're not supposed to do it...They tell you not to do that...But we felt, you know, when you work with a bunch of guys, you become close...And [the miner helper] told the boss..."Hey, I'm not leaving." Because the boss said, ..."Hey, let's go"...you know, and [the miner helper] said..."We're not leaving [the buggyman]"...and then we started going back in.

The buggyman, meanwhile, had traveled the 3 Left intake escapeway to an area outby the fire. It was some time before the crew got back together.

2 Northwest - Adelaide

Choices required of the 2 Northwest group were affected by the fact they had two experienced people with them. Their face boss knew the mine well and one of the shuttle car operators had been a mine rescue team member. When the crew entered heavy smoke on their track, a decision was made to stop the mantrip:

> The guy that was driving stated that he didn't think we'd better go any more, so that was more or less a judgment call. We could have gone down the line—you could have put your rescuers on and you could have kept going out [on] the mantrip, but the pole...would have been off...I don't know how many times, on the way out, that the poles were jumping pretty frequently going out of there...So...we stopped the mantrip and got the rescuers, took those and went back up to the section.

On the way back into their face area, the former mine rescue team member helped everyone put on a self-contained self-rescuer:

> This time we got everybody together and [the face boss] said, you take the back, I'll take the front. Don't let anybody in back of you, you know, and we'll keep everybody together.

The face boss led the group toward their intake escapeway. At the entrance to this entry, crew members took additional SCSRs that were stored there. Then,

grouped together with their face boss leading and the shuttle car operator bringing up the rear, everyone proceeded out the intake escapeway. After traveling 500-600 ft, the group encountered dense smoke. The face boss then decided to enter the right return, which was a designated secondary escapeway:

> Every 3-by-3 door, [the face boss] would go check...We done this for, I counted, my calculation was 55 breakthroughs.

When the men reached the No. 3 stopping, which was outby the fire, they found the air to be clear. Finally, the face boss saw the shift foreman and notified him that everyone from his section was out.

3 Left - Adelaide

A section foreman and nine crew members were on 3 Left, which was a retreat section. The group started out on their mantrip. After traveling "four or five breakthroughs," they entered smoke. At that time they made a decision to backtrack toward the face and get into their primary escapeway. The group walked two breaks and found a door leading into their intake escapeway:

> So we went down the intake approximately, oh, I don't know, maybe seven or eight breakthroughs, it's hard to say the number right now, but it wasn't very far. And we were getting a lot of smoke in there and it was rubber smoke. You could smell it just as plain as could be; it was a belt burning.

A decision was then made to get into the alternate escapeway. The group had not gone very far in this return entry when they again encountered smoke. At this point the SCSRs were donned:

> I remember thinking to myself, I said, "This is stupid, I know better than to walk through smoke without putting that thing on because you don't know how much CO's in it." And that's when we stopped and put them on. And then, we kept on going out of the return. We got down to where our overcasts was and there was an overcast there that we couldn't cross. It was leaking so bad, and the smoke was so thick we couldn't get over it.

The face boss, deciding to get back into the intake escapeway through a door in the overcast, became disoriented temporarily:

> And then we had to have a little team meeting there. We knew there was an intake; the intake escapeway was still in that area if we could

> find the right door to get into it...The subject of barricading was brought up, but that's—what are you going to barricade if it's full of smoke everywhere?

After figuring out the proper direction of travel, the face boss led everyone over the overcast and out their intake entry. One of the roof bolter operators began having trouble, presenting the group with another decision:

> When [the roof bolter operator] went down, we was all single file and I was last...I noticed no one turned around at that point...I spit out the mouthpiece and I hollered as loud as I could...And only two people come back...It made a mean feeling in me that it was every man for himself at that point on.

Approximately three crosscuts from clear air, the group met Adelaide's shift foreman, who had been traveling the entry looking for them. He helped everyone get out from there.

4 South - Brownfield

The miners escaping from 4 South were troubled by some elements that colored their abilities to make decisions. Awareness of past mine disasters (such as a recent fire at Utah Power and Light's Wilberg Mine, in which 27 miners died) revealed to these workers how deadly a mine fire could be. Such knowledge made any uncertainty about the scope of this fire even more problematic:

> We all encountered a panic situation where we didn't know where the fire was, we didn't know the extent of it, and my personal thoughts were that it was a Wilberg disaster, and that's all that was in my mind...Where is that smoke coming from? How bad is it? Well, I panicked...I know I did, I'll admit it...Everybody, I think, did.

A complex background problem also hindered an efficient escape. Although the miners had received training on self-contained self-rescuers, few had any actual experience wearing the apparatus. During their escape, they found the device was difficult to breathe from and made communication almost impossible:

> I was with [the miner helper] and [he] was having very difficult breathing through it...He was gasping for air...[The inspector] was trying to help [him] breathe...And then with the mouthpiece in, it's real hard to communicate—you can't hear one another...Some of us took the

mouthpiece out to try to speak and then to even breathe...It was so hard to breathe through that mouthpiece.

In addition to not knowing the location and extent of the blaze in their mine, these side issues were on the workers' minds as they attempted to determine options available and to choose the best course of action for themselves.

One miner had so much trouble that assisting him became, in itself, a background problem that had to be dealt with, as evidenced by three different perspectives:

Miner helper: The smoke started getting pretty thick...You couldn't really see where you were going and I was having a lot of trouble getting enough air...I'd go a ways and I'd stop and a couple guys [stayed with me]...I was pretty shook up; I guess I panicked and a lot of stuff went through my head...Hell, you didn't know where it was coming from or anything...Finally...I just couldn't go anymore.

Inspector: I couldn't get him back up again...He looked at the mechanic...I saw him look at the mechanic and he said, you guys go... You just leave me here...I can't go no more...I'm just going to stay here... I looked at the mechanic and I said I got to go...there is no sense in me staying...I can't breathe now.

Mechanic: I didn't know my way out of there...I lost all orientation... I knew my way out, but I forgot...It was just a panic thing...I thought, well, [the miner helper's] not going to make it, I'm going to try and get out...I was only about a hundred foot from [the miner helper] when I came through the overcast and I opened the door and I saw No. 7 and I thought [wrongly], good, this is fresh air...I thought well I'm going back in to get [the miner helper].

Essentially, facing so much uncertainty about the fire, the miner helper gave up because he had projected a worst case scenario in which the crew would have to travel through smoke all the way out of the mine. The inspector, convinced that his self-contained self-rescuer was about to fail and forgetting that he was carrying a spare under his arm, wanted only to get out of the section. The mechanic, believing himself to be in No. 7's intake aircourse, concluded that he had left the miner helper only some 100 ft from safety, although the distance was actually much farther. Based on his incorrect estimate, the mechanic decided to go back for his buddy. In reality, all three men based their actions on assumptions that were false when, if the facts had been clear, they might have made other choices.

5 South - Brownfield

The old adage that "a little knowledge is a dangerous thing" seems to have a particular relevance when it comes to perceiving and assessing one's options at specific moments in a mine fire. Other times, however, a little knowledge can be rather beneficial. As can be seen from the following comment about the escape from 5 South, prior experience in an environment may afford a sound basis for simplifying an individual's application of some elements in the judgment and decision-making process:

> I know one thing I had going for me, when I first went up into that unit it wasn't 3 days after that I went down the return with one of the bosses...So if somebody had never went down it at all...I'm sure they're probably more uptight about the situation than I was...At least I had an idea where I was going...and then another good thing, we had bratticemen with us and they knew their way down through there, and the boss was there too.

Additionally, an ability to place the crisis cognitively in one's surroundings can, by reducing uncertainty, foster a positive attitude:

> So we went and then we run into two other guys coming down...and then they told us where the fire was at...4 South sidetrack where the motor was setting...So then we had an idea how far we had to go, so it took a little bit of pressure off 'cause we knew we was goingCwe had a pretty good chance now.

When knowledge acts to minimize sources of stress, therefore, it need not be comprehensive to have a positive function.

6 West - Brownfield

Choices made during the escape of those three workers on 6 West Mains were affected by stress along with any knowledge and skills brought by each worker to the situation. The heavy smoke they encountered created stress by impeding their ability to see and by forcing them to use relatively unfamiliar oxygen-generating breathing apparatus. This in turn led to a level of anxiety that hindered clear thinking:

> I got down to 5 South...and couldn't find my way...the door wasn't there where I knowed there was a door...but I mean, I didn't waste no time hunting...Whenever I walked past and couldn't see the door or feel it,

I didn't[C]I went back the next day and the door was there.

The miner's knowledge of his environment told him a door should be at a given location and that he ought to go through it in order to continue his escape. Because he could not find this door, the worker had to discover an alternative route. In this instance, then, prior knowledge (of the door's location) was not an element that was applied to aid the worker's evacuation.

In the maintenance foreman's opinion, cognizance of 6 West Main's designated escapeways may actually have been misapplied and consequently had a negative effect on decisions that were made during his attempt to evacuate the section along with his two coworkers:

> You try and pay as much attention in class as you can on your escape routes and stuff, and I guess I panicked a little bit when I seen the smoke in the belt line as heavy as it was...I could have went...back... and...over and...down 6 aircourse and been scot free of everything... I wouldn't have even needed to don my rescuer...But...you're trained to follow your escape routes.

Although the objective outcome of considering only designated escapeways is known (all three individuals on 6 West survived), it did limit those options available to the escaping miners. As for the possibility that these men, in adhering rigidly to their training algorithm for mine evacuation procedures, may have overlooked a better route of travel: "I know if it ever happened again, I would explore...all routes of exit before I made a real quick decision."

7 Butt - Cokedale

The decision-making on 7 Butt was done by the construction foreman, who possessed a great deal of "mine wiseness" and who took charge immediately:

> That was one of the things that I had to commend the people for. I was a foreman in charge of that area, and when I said to these people what we had to do, there was no second-guessing my decision. These people were counting on my knowledge that this was right and there was no second guessing it. I had no problem with these people as far as my decision.

The construction foreman reported that he knew evacuation would be necessary as soon as he saw the amount of smoke that was coming down their fresh air intakes. He then had to choose between going into 7 Butt or 8 Face Parallels to warn workers that they were in danger:

> And I made the decision to go into 7 Butt to get these people because they were far enough away from communications that somebody would have to go and recover these people and being that I was there, I was the one to go and get these people and get them out...But the dispatcher could get in contact with [the 8 Face Parallel] people and tell them that they had to evacuate because of the amount of smoke that was coming in.

As mentioned previously, the construction foreman attempted to get everyone out in vehicles. Looking back on that choice, he reported he would have taken a different option if he could do it over:

> As I brought these people out, we would have stopped when we got to the smoke, and at that time everybody had their SCSRs on and then we would have walked...I don't know if I told the dispatcher or not that I was going out the return escapeway to Crystal. But I would have been a little bit more organized the next time as far as my...communications... to the surface, my travel, and how many people I had with me.

One reason the construction foreman made some decisions at the smoke that he later second guessed himself on was because of a significant background factor:

> I was anticipating the trolley switch burning out. There's quite a bit of smoke with it...and I was assuming that if the trolley switch was burning, from what I heard...that would be the main concentration and... we would go through here. And it was like second-guessing instead of coming to the smoke area, getting together, and then walking out.

Once the group got into their return escapeway, the construction foreman began checking mandoors leading to the track entry. He did this in order to determine when they had reached clear air. Upon getting outby the fire, the construction foreman called outside and arranged for his crew to be picked up and transported to the surface.

8 Face Parallels - Cokedale

Lack of knowledge was an important factor in perceived options and choices that confronted the group from 8 Face Parallels. Initially, the nine miners there tried to walk out their track entry. In a short time, however, they hit smoke and had to make another choice. A general foreman who was with this crew decided the next option should be to go out their intake escapeway: "You're always trained intake, track, intake, return. I tried track, that was no good, tried intake."

The problem was that this intake did not extend to the shaft bottom. The only person who seemed aware of this fact at the time was a trackman who had been delivering a load of rails to the area. He was unfamiliar with that part of the mine, however:

> I was like the most greenhorn out of the group, so ICI pretty much kept to myself what my thoughts were. The game plan [was] that they were going to walk out the intake. Now at that point, I can't say how I knew this, I obviously heard it from somebody at some point and it stuck with me, but I was told that...the intake went out onto the track. According to the old laws...they didn't have to [take] it to the shaft...And that stuck with me, and when they decided they were going to walk the intake, I specifically said to [the general foreman], "We can't go out the intake. That's just gonna take us right under the smoke." No, we'll walk the intake. Well, you know anarchy can't reign.

The group proceeded about six breaks in their intake and encountered heavy smoke again. At that time they decided to return to the face and try to go out their secondary escapeway. At the section loading point, another mistake was made. Because of stress and unfamiliarity with the section, the men entered the wrong return. After traveling a few breaks, someone realized there were no reflectors indicating that this entry was an escapeway. The group was forced to backtrack in order to reach the correct entry.

On their way out in the alternate escapeway, group members faced other choice points. When they reached their section regulator, it was decided to stop briefly. A general inside laborer, who had once been a maintenance foreman, suggested to the general foreman that the two of them investigate conditions ahead. Leaving everyone else at the regulator, these individuals went a few hundred feet on. When the smoke became worse, the general foreman expressed reservations about continuing that way:

> He said, "We can't lose the smoke this way." I said, "I know...we have to go through this—go out the return. Smoke, no smoke, or whatever, we can't keep changing our minds—we'll be here forever." So he agreed.

The general inside laborer then went back to get those workers waiting by the regulator. Some of them were already discussing whether to put on their filter self-rescuers (FSRs) or don their SCSRs. The general inside laborer and a mechanic donned self-contained self-rescuers. Everyone else put on their filter devices:

> We were always trained [that] at the first sign of smoke you should [put on your SCSR]. At the first sign of smoke I didn't put it on because, you know, they were saying fairly confidently that it was probably just a hanger burning...[Later] the instances that I pointed out...led me to believe that this man wasn't going to get us out of there in a safe period of time...You have an hour with that SCSR. Not knowing where I was, that's the reason I didn't put it on immediately.

The group traveled for some time until the filter self-rescuers became hot. At that point, the men knelt in a circle and donned their SCSRs. They then proceeded outby in the return, checking through mandoors for fresh air.

It seems from the preceding comments there were two factors that had a disproportionate impact on the choices miners made. The first was their internal state, specifically their knowledge (or lack thereof) regarding how elements in the environment were supposed to fit together. While all of the workers generally understood what it means to have the haulage belt on a neutral split of air, for instance, few seem to have considered the possibility that something as simple as an open door, rather than a raging blaze, could explain the contamination of this air. In the same vein, although the miners had internalized an awareness of what their self-contained self-rescuers were supposed to do, not many were prepared for the actual experience of breathing with one. The second factor influencing the miners' choices concerns the amount of uncertainty stemming from a lack of adequate information. Those workers who did not know the fire's location, or its source, were inclined to believe the worst. Their choices tended to be based on a perceived need to travel some miles with close to zero visibility before the oxygen in their apparatus ran out. For the few miners who had been told where the smoke was coming from and what was causing it, the goal was simply to get outby some point inside their mine.

Actions

Once a choice is made it then can be executed. Any action taken by an individual or group therefore has real consequences that are frequently used by others as a basis for an analysis of the quality of this choice. The actual decision-maker, however, aware of all those factors that affected the process, may evaluate his or her choice using different criteria. Those who escaped from the three fires discussed options they exercised and reflected on the quality of their actions.

1 Right - Adelaide

The first action taken on 1 Right was a delayed one: "The phone was

ringing but we never answered it, you know, because usually the boss would take care of that." This delay, combined with the holdup caused by a subsequent miscommunication between the buggyman and miner operators, could have had severe repercussions:

> Another 5 minutes and we wouldn't have been able to come out the way we did because that overcast did go and collapse. We'd have had to find another route out of there. And it was already 45 minutes...I only had 15 more minutes on that self-rescuer because they said it only lasts an hour. And we were just fortunate.

A second significant action was when the crew abandoned their mantrip. The miner operator discussed an option that occurred to most of the groups but was not executed successfully by any of them:

> If we had known, we probably could have put the self-rescuer on [and ridden] out in the mantrip. But then we thought about that, and when you have a mine fire, you're [liberating] other gases too, and the pole on this [mantrip] always jumps off. And what we were afraid of is [the pole] jumping and a spark and having an explosion. You know, we were a little concerned about that.

In view of these concerns, therefore, the group explored their possible choices and decided the best course of action was to go out their left-side return airway.

A heroic but ill-advised action was undertaken when the crew reached fresh air and found one of the buggymen missing. A bolter operator, the miner helper, and a bratticeman volunteered to go back and look for him. The miner helper borrowed the face boss's light so he could tie it to a water line that ran in the left return. This light was to indicate the point at which the three men should make a left turn to find the door they had come through. Leaving the bolter operator at the water line, the miner helper and bratticeman continued on to the overcast where the buggyman had separated from the group:

> When I got to that overcast, as soon as I was going up on the approachway, you could just feel something collapse. I mean, the smoke, you couldn't even see your hand in front of you.

When the overcast blew out, the bratticeman, who had been holding onto the miner helper's belt, drew him away from the approach. The two men then retreated back along the water line, running over the bolter operator in the dense smoke. All three individuals then crawled until they saw the light they had tied to the water line. They turned left into the break and went back through the

mandoor to fresh air.

2 Northwest - Adelaide

Perhaps the most significant action on 2 Northwest took place at the beginning of the miners' escape. The face boss quickly assigned the former mine rescue team member to bring up the rear as everyone traveled out. The boss stayed near the front and tried to keep the men from walking too fast—a tactic that was appreciated by the utilityman:

> No, he was like in back of me there and we just—we all stuck together real well. You know, if I got too far or [the bratticeman who] was with me, he'd get out in front of me and if we got out too far, the boss or somebody just said, "Take a break." And the one guy was having trouble and he said...that he needed to rest some, and we just stopped and rested with him.

Because the face boss did not know the fire's exact location, he would open each door in the stopping as the group progressed. This offered the workers another opportunity to stop and catch their breath. Overall, as the data show clearly, 2 Northwest had the most orderly escape of any of the eight groups in this study.

3 Left - Adelaide

It was mentioned earlier that some of the 3 Left crew balked at crossing the overcast at 3 Left junction. The face boss decided to get back into their intake escapeway through a door in the overcast. At that point, according to the miner helper:

> We got confused and we started going back into the section till we run into the first door, and we just made a complete circle and come right back to that main overcast again...He made a right instead of a left the first time.

The boss, coming through the door again, knew which way to go the second time because he stopped a moment to feel the air current on his face. "Once we made the left, we were in good shape."

4 South - Brownfield

On 4 South the seven miners and one Federal inspector started their escape by going down the section's belt entry: "[The boss] had noticed there was some smoke already coming up [the intake] and they figured the return would be filled up too, so we couldn't go down [that] way...So they figured the belt would be the best way to go." At the beginning of this evacuation, all eight individuals were hurrying along the belt. Not all of these workers, however, had the ability to keep up this rapid pace. Therefore, two groups were formed. The section foreman went ahead in order to keep up with three workers who were moving rapidly, leaving the inspector with slower members of the crew. This second group was also divided as one person in it continued at a slow but steady pace, essentially escaping alone. Those left behind were the miner helper who had been having difficulty, along with the mechanic and inspector who were trying to help him. Finally, these two individuals left the miner operator as well.

As was indicated previously, the mechanic, believing that he had entered 4 South's intake aircourse only a short distance from where he had abandoned the miner helper, went back after him. The mechanic and section foreman, who had by this time also returned, assisted the miner helper to the track entry. All members of the crew then continued outby the burning motor.

The interview data show widely divergent opinions about the appropriateness of 4 South workers' actions during their escape:

> The one thing we did wrong, it come out that we was two different groups of four...We kind of split up and got ahead of each other.

> I didn't want them splitting up...I was glad that the inspector was there because I felt he's going to watch [the slower] people and I'm going to watch the other group.

> It's nice if we could have stayed together...but nobody knew where the fire was and everybody was trying to get out as best they could...It didn't bother me that I was left behind.

> Actually, [having the whole crew stay back with the slowest person] might have been worse...Everybody fumbling around...[The others] weren't able to see this man in, I guess what you'd call a panic state and maybe that's good for them.

It is interesting that the first statement, implicitly critical of some miners leaving others, was made by a worker in the first group out. The last two quotes, which suggest that leaving was at least understandable, were taken from miners in the

slowest group. During their interviews, most of the individuals from this section reflected at length on their personal decisions to leave (or not to leave) others behind. Obviously, the choices made by each miner were arrived at within a context of extreme stress:

> It did cross my mind a couple of times that we should be sticking together and come out as one group...We had one man that sat down and didn't want to go any further and there was four of us ahead...There could have been four extra guys to at least help the guy, something... You never know what you're going to do until you get in a situation...but definitely we should have stayed together.

> I didn't want to go to the head of the pack—I wanted to stay and know where my people are...That was my first concern...I just didn't like the idea, but I didn't want [the faster group] taking off the way they were... I can't sit on them all...So long as [the inspector] would go with that group, I'd go with the faster group.

> I'm back here with this guy and he's having all this trouble breathing and now I'm having trouble breathing...there's no sense in me staying...I can't breathe now...I know where I'm at...I can send somebody back...I'll go out and get somebody...If it's only to the main track, there will be somebody, I hope, out there...I can send them back and I know exactly where you're at.

As can be seen from their accounts, the trip off 4 South was very problematic for these workers. Even though everyone lived through the experience, there was little consensus as to whether or not the best choices had been made.

5 South - Brownfield

Like the miners on 4 South, those in 5 South crew began their evacuation down the belt entry: "We said we couldn't go down the intake because that's where the smoke was coming from...So everybody decided to go down the belt line." These workers, who stayed close together throughout their escape, continued along the belt line until they hit heavy smoke and then crossed into the return aircourse. They traveled down the return entry, checking through doors for clear air as they went. At one point they finally detected fresh air, crawled through this door, and it led them out onto the track.

An official investigation was conducted after the blaze. In this inquiry there was some criticism of the workers' choice of escape routes. The belt entries traveled by those miners from 4 South and 5 South had not been designated as

either primary or secondary escapeways. The Federal inspector who escaped the fire addressed this criticism during his interview:

> It had been suggested through the course of the investigation...that we... didn't...follow the proper escape procedures because we didn't utilize the return aircourse as an alternate escapeway...I promptly informed this person...you had smoke coming up the intake, there's only one way for that smoke to go and that's back down the return...the first thing I did was check the belt...and the belt was clear...So I know the belt entry had permanent stoppings...I had no reason to believe that that belt entry should have been contaminated.

While the correctness of these miners' actions can be questioned, the inspector was sure that, given his situation, the best escape route had been taken.

As was also suggested during the investigation, there may have been an escape route for 5 South that was objectively better than the one they chose:

> From what we were told...instead of going down the return, we could have went up...Being [the fire was in] 6 West Mains (which we didn't know at the time), we probably would have been better off going up the hill to 6 West Mains and across.

This miner agreed that, with the advantage of hindsight, a better route of escape might have been chosen. He went on to note that decisions being made by the miners on 5 South during their escape were executed with incomplete information about the fire and the condition of the mine. So, without the luxury of prescience, the workers used their best judgment.

6 West - Brownfield

After picking up their self-contained self-rescuers, the two miners and State mine inspector who were working in 6 West Mains began their evacuation: "I was going to ride the jitney out of there, but [the inspector] wouldn't let us, so we went on foot." The men started down 5 South's intake aircourse, walked approximately 50 ft and hit thick smoke: "When I turned around and said we got to go back, [the inspector] says no, and I says you can do what you want to do, I'm going back." All three did backtrack, entered the return, and continued their retreat out of the section until they came to an overcast where the miners from 5 South were encountered: "then I was relieved a little bit because I knowed that boss coming with that crew was real familiar with the mine." After crossing this overcast, the miners began hunting for a door that would take them into the intake aircourse. One miner from 5 South called and said that they had just

passed a door. Everyone returned to that door, went through it, and eventually got into clear air.

During their interviews many of the miners speculated about the State inspector's decision not to permit use of the jitney in the evacuation of 6 West Mains section. Even though the inspector based his actions on the knowledge that a mine fire can liberate potentially explosive gases and that these gases might be ignited by an electrical motor, there was still extensive debate centered upon whether or not the people on that section should have ridden out.

One of the miners who had been on 6 West Mains and who had complied with the inspector's directive not to ride out, thought that the decision was nevertheless a poor one: "I know one thing, if it ever happens again and there's something to ride, I don't give a damn who—they can do with me what they want when they get me outside, but I'm riding." Later in their escape, when the three men hit heavy smoke, this miner refused to regard the inspector's initial refusal to backtrack and enter the return aircourse: "I said, 'You can follow me or do what you want.' At that point I didn't give a damn who followed me or who didn't, I was getting out of a heavy concentration."

Even though it meant retracing their steps, the worker considered going back in order to enter the return an appropriate choice:

> When I encountered the really heavy smoke...We could have probably made it down through there...I'd have probably made it just as quick or quicker...because I [backtracked] and then we went further down [past] 4 South to come out [into fresh air] than I would have if I [had stayed in] the intake...But I'm glad I went the way I did because we might have went down further and encountered smoke...you wouldn't have knowed where you was at...you might have went in circles.

While analyzing his actions, the miner pointed out that because of uncertainty about the true condition of his intake aircourse, he had to assume that smoke in this supposedly smoke-free entry meant there was possibly fire as well. The thought that they very well might "run right into the fire" is what made this worker seek alternative escape routes once he and his companions encountered smoke in their primary escapeway.

7 Butt - Cokedale

The group from 7 Butt intended to ride out in vehicles. A mechanic, who was in the lead, stopped his jeep as soon as he encountered heavy smoke and began putting on his self-contained self-rescuer. The construction foreman, who was following, collided with the stopped jeep. This caused the wireman who

was riding with him to lose his cap, cap lamp, and battery. A general inside laborer, who was operating a tandem motor carrying himself and a trackman, ran into the foreman's jeep. After retrieving the wireman's cap and other gear, all five men boarded the mechanic's jeep and continued. They had not gone far, though, when they collided with an abandoned locomotive. This time, the wireman lost his cap, cap lamp, and battery for good. He then had to be helped by the others. This is the point at which these members of the group got into their return. They then waited for three people who had not followed them into the smoke.

The remaining three workers in this group were traveling in a portal bus. A mechanic and a general inside laborer had stayed on the section briefly to rendezvous with a fire boss who was conducting his preshift examination. When they encountered smoke, the fire boss, who was driving, backed the portal bus out into clear air. They heard, over the mantrip's speaker phone, conversations that ensued from the collisions up ahead. The three men decided to take another route out:

> So we put our self-rescuers on. We looked into the intake escapeway; it was filled with smoke. So we crossed over to the return and there was just starting to get smoke in there. And we started out there and we went out the return and we tied back in with [the construction foreman] and our group that left right before us 'cause we waited for the fire boss.

The eight workers proceeded out their return. Two individuals stayed close to the wireman who had lost his cap and light, reassuring him and helping him along until they came to the set of double doors through which everyone exited.

8 Face Parallels - Cokedale

Execution of decisions was a problem on 8 Face Parallels because the group's familiarity with the area did not extend to their escapeways. The general foreman addressed this issue in regard to his choice of their primary escapeway even though the fire was in a track entry:

> And it's my fault that I didn't know the...escapeway was dumping on the track. Of course, I didn't know where the fire was at either.

Once the group reached their section regulator and the general foreman, accompanied by a general inside laborer, explored ahead and saw more dense smoke, they were faced with another decision to execute:

> And we put [the filter self-rescuers] on at that point in time when the guys came up to me and I signaled everybody. I already had mine on

> and my clips on; everybody put them on...It was an old return that I'd walked and we put those on and we may have made about a thousand feet. We didn't make it anywhere near the mandoor to Steiner. And boy, they were cooking. They were cooking and we all knelt down and put the [SCSRs] on...We knelt in teams...helping each other and checking everything. Maybe 3, 4 minutes. It's hard to tell.

This group proceeded on out under air from that location, eventually joining up with the miners who had escaped out of 7 Butt.

Discussion and Analysis of a Particular Case

The interview data show that everyone who escaped from the three mine fires experienced numerous episodes of problem recognition, evaluation, decision-making, and action while being influenced by their internal state and the environment. In order to understand the decision-making that was done by these workers during their escapes, background variables were identified and included in a model. This heuristic device was then used as a starting point for analyzing the characteristics of decisions made during the emergency.

The escaping miners were continually processing information and acting upon their perceptions of the mine environment. Though some of the workers spoke of being in a state of "panic," they do not tell of any points at which they were not actively evaluating their situation and attempting to continue to safety. Even those miners who had the most difficulty and, in fact, could not escape without assistance, were thinking through their available options. This can be seen in the attempt by the 4 South mechanic to switch from a self-contained self-rescuer to a filter self-rescuer just before the others came back to help him. In this extremely dangerous situation, the will and the ability to make decisions was not lost. It is likely that the decision-making process will exist in all contexts and, given the right techniques, will be available for study.

The authors of this chapter are not experts in either disaster management or mine rescue. A group of mine rescue experts were, however, brought together to review the reported actions of those miners on 4 South. They then worked with a cognitive psychologist to develop a simulation problem based on the event [Cole 1989]. This problem unfolds over time and only offers information and alternatives that would have been present in the environment at a particular choice point. From the simulation, then, it is possible to arrive at some insight into what these experts agreed on that would be either a good decision or a poor one in the context within which it occurred.

Perhaps the worst decision, in terms of any attempt to allay stress during these workers' escape, was made by the shuttle car driver on 4 South. It will be remembered that this individual hung up the page phone and went to warn his buddies rather than stay on for another moment and try to get more information

about the fire's location and magnitude. Put simply, whether the fire boss actually knew any more details than he was able to communicate is immaterial: the shuttle car driver saved a minute—2 at most. Even coal mines do not burn up in that space of time.

Interestingly enough, those experts who constructed the mine fire simulation agreed with the Federal inspector that 4 South's belt line was the one good escape route available. This inspector could not know that it would become filled with smoke, nor could he foresee those difficulties encountered by a crew member (which were made worse by cramped conditions along the belt). A poor decision was to undertake travel down this entry without first calling outside to inform someone that the workers would not be using either of their designated escapeways.

Another bad decision was to move into the belt line without first donning self-contained self-rescuers. Even smoke-free air can be contaminated by carbon monoxide. In fact, since brattices tend to leak, there could have been more CO in the "neutral" air along their belt than in the smoke-filled but rapidly moving air of 4 South's intake entry. A good choice was to check through the mandoors leading into the primary escapeway periodically, thus enabling crew members to get into fresh air as soon as possible, since they were having problems with their self-rescuers.

Regarding use of their emergency breathing apparatus, expert opinion was that the crew members made some decision errors that could have killed them had carbon monoxide levels been high. For one thing, they waited too long to don their apparatus. Secondly, almost all of the workers "cheated" by taking the mouthpiece out to breathe in areas where smoke was not so dense. This was done despite the fact they had no way to check for carbon monoxide in their atmosphere. Finally, two individuals used their devices to assist the miner helper (these apparatus are approved for self-rescue only), when a better course of action for them would have been to remain outby the fire and wait for a mine rescue team to arrive. While there was some debate among the mine rescue experts as to how filter self-rescuers and self-contained self-rescuers may be employed optimally, they were in agreement about the notion of "self" rescue. This led them to conclude that those four workers who left their slower-moving comrades behind and continued outby the fire made a good decision. Their reasoning was that since the self-contained self-rescuer has a finite supply of oxygen (about an hour) and 4 South's crew had no idea where the fire was located, to stay with the miner helper might well have spelled everyone's doom. Furthermore, someone should have gone on outby in order to inform mine rescue personnel where to look for those who could not make it (since they were not in either the primary or secondary escapeway).

In summary, even though the assessments of decision-making quality discussed above result from a consensus of experts, there is still room for debate. The point here is that research that focuses on judgment must include scrutiny

not only of decisions that are made, but also of real-world variables that influence them. The quality of any decision may have little or no direct relationship to the eventual outcome of its execution in a given situation. This is because a decision-maker is constrained not only by the stress of the situation or personal knowledge and attitudes, but also because he or she can only weigh information that is available. Acknowledging the complex context of concrete decision-making environments is a first step to understanding the skill of decision-making and learning to evaluate the abilities of decision-makers.

References

Baumann A, Bourbonnais F [1982]. Nursing decision-making in critical care areas. J Adv Nursing *7*(5), pp. 435-446.

Begland RR [1979]. The analysis of "soft skills": a implementation strategy. In: Proceedings of the 21st Annual Conference of the Military Testing Association. ED 190 648, pp. 328-336..

Biggs JB [1968]. Information and human learning. North Melbourne, Victoria, Australia: Cassell Australia, Ltd.

Billings CE, Reynard WD [1984]. Human factors in aircraft incidents: results of a 7-year study. Aviat Space Environ Med *55*(10):960-965.

Brecke FH [1982]. Instructional design for aircrew judgment training. Aviat Space Environ Med *53*(10):951-957.

Cole HP, Berger P, Vaught C, Haley J, Lacefield W, Wasielewski R, et al. [1988]. Measuring critical mine health and safety skills. Lexington, KY: University of Kentucky. U.S. Bureau of Mines contract No. H0348040, pp. 202.

Cole HP [1989]. Escape from a mine fire: a latent image simulation. Beckley, WV: U.S. Department of Labor, Mine Safety and Health Administration, National Mine Health and Safety Academy.

Endsley MR [1988]. Design and evaluation for situation awareness enhancement. In: Proceedings of the 32nd Annual Meeting of the Human Factors Society. Vol. 1, pp. 97-101.

Flathers GW Jr., Griffin WC, Rockwell TH [1982]. A study of decision-making behavior of pilots deviating from a planned flight. Aviat Space Environ Med *53*(10):958-963.

Godden D, Baddeley AD [1979]. The commercial diver. In: Singleton WT, ed. The study of real skills: Vol. 2. Compliance and excellence. Baltimore, MD: University Park Press, pp. 157-177.

Hedge A, Lawson BR [1979]. Creative thinking. In: Singleton WT, ed. The study of real skills: Vol.2. Compliance and excellence. Baltimore, MD: University Park Press, pp. 280-305.

Janis I, Mann L [1977]. Decision-making: a psychological analysis of conflict, choice, and commitment. New York, NY: Free Press.

Jensen RS, Benel RA [1977]. Judgment evaluation and instruction in civil pilot training. Report No. FAA-RD-78-24. Champaign, IL: University of Illinois.

Kinston W, Rosser R [1980]. Disaster: effects on mental and physical state. In: Pugh M, ed. Collective behavior: a source book. St. Paul, MN: West.

Lerup L, Cronrath D, Liu JKC [1980]. Fires in nursing facilities. In: Canter D, ed. Fires and human behavior. Chichester: Wiley, pp. 155-180..

Mallett LG, Vaught C, Brnich MJ Jr. [1993]. Sociotechnical communication in an underground mine fire: a study of warning messages during an emergency evacuation. Saf Sci *16*:709-728.

McHugh P [1968]. Defining the situation. Indianapolis, IN: Bobbs-Merrill.

Pew RW [1994]. Situation awareness: the buzzword of the '90s. Gateway *5*(1):1-4.

Sime JD [1980]. The concept of 'panic.' In: Canter D, ed. Fires and human behavior. Chichester: Wiley, pp. 63-81.

Thomas WI [1923]. The unadjusted girl. New York: Social Science Research Council, pp. 41-44.

Stone RB, Babcock BS, Edmunds WW [1985]. Pilot judgment: an operational viewpoint. Aviat Space Environ Med *56*(2):149-152.